An IEEE 1451 TEDS Compiler
and Serial Network Compliance Tester

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www.eesensors.com

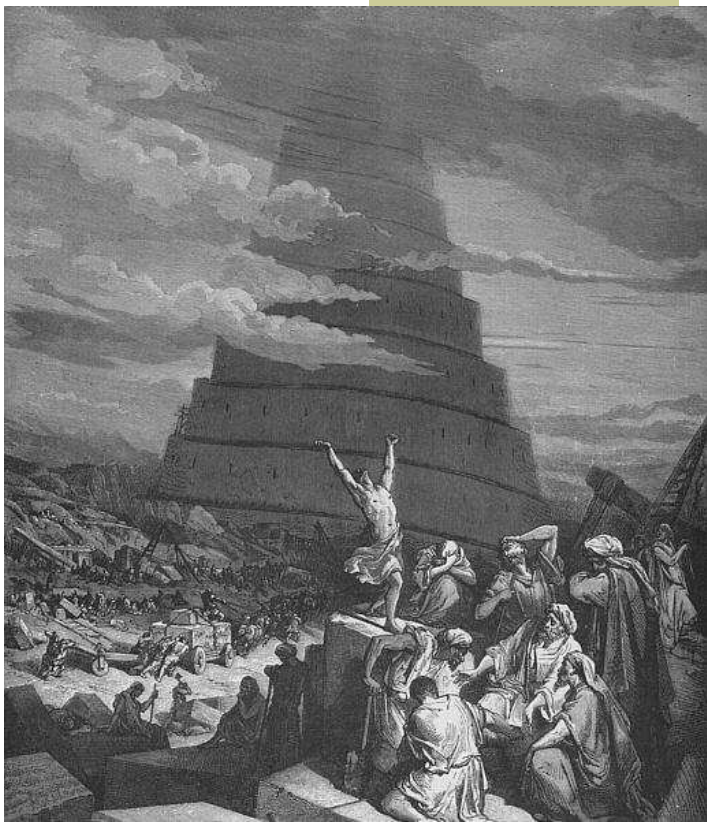
Sensor Standards Harmonization -- Sensors Expo
Chicago, June 2006

Goals

- To develop a simple IEEE 1451 TEDS compiler (writer/reader), including linear calibration procedure
- To develop an Internet-compatible compliance tester for the standard (using a serial bus with extensions to other buses/networks)
- Demonstrate the tester using an RS232 (Dot 2) TIM
- Suggest a pathway for harmonization with other standards

IEEE 1451 – the Universal Transducer Language

- Over 100 sensor network protocols in common use
- Narrow solutions and borrowed protocols have not worked
- IEEE 1451 is the best universal solution
- Sensor engineers in the fragmented sensor industry need a simple method of implementation
- How can it be done?



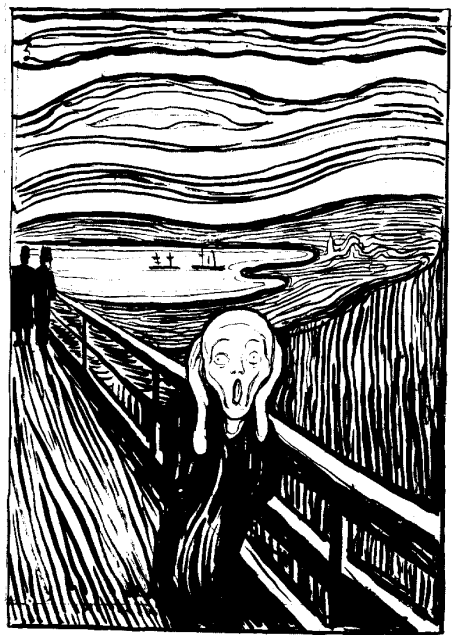
The Tower of Babel

IEEE 145.0 (Dot 0) Advantages

- Comprehensive enough to cover nearly all sensors and actuators in use today (not 20/80% approach)
- Many operating modes
  (buffered, no-buffer, grouped sensors, timestamps, timed data, streaming …)
- Extensive units, linearization and calibration options
- Multiple timing and data block size constraints handled.
- Compatible with most wired and wireless sensor buses and networks (point-to-point, mesh, TIM-to-TIM, mixed networks).
- Efficient binary protocol (especially suitable for wireless)

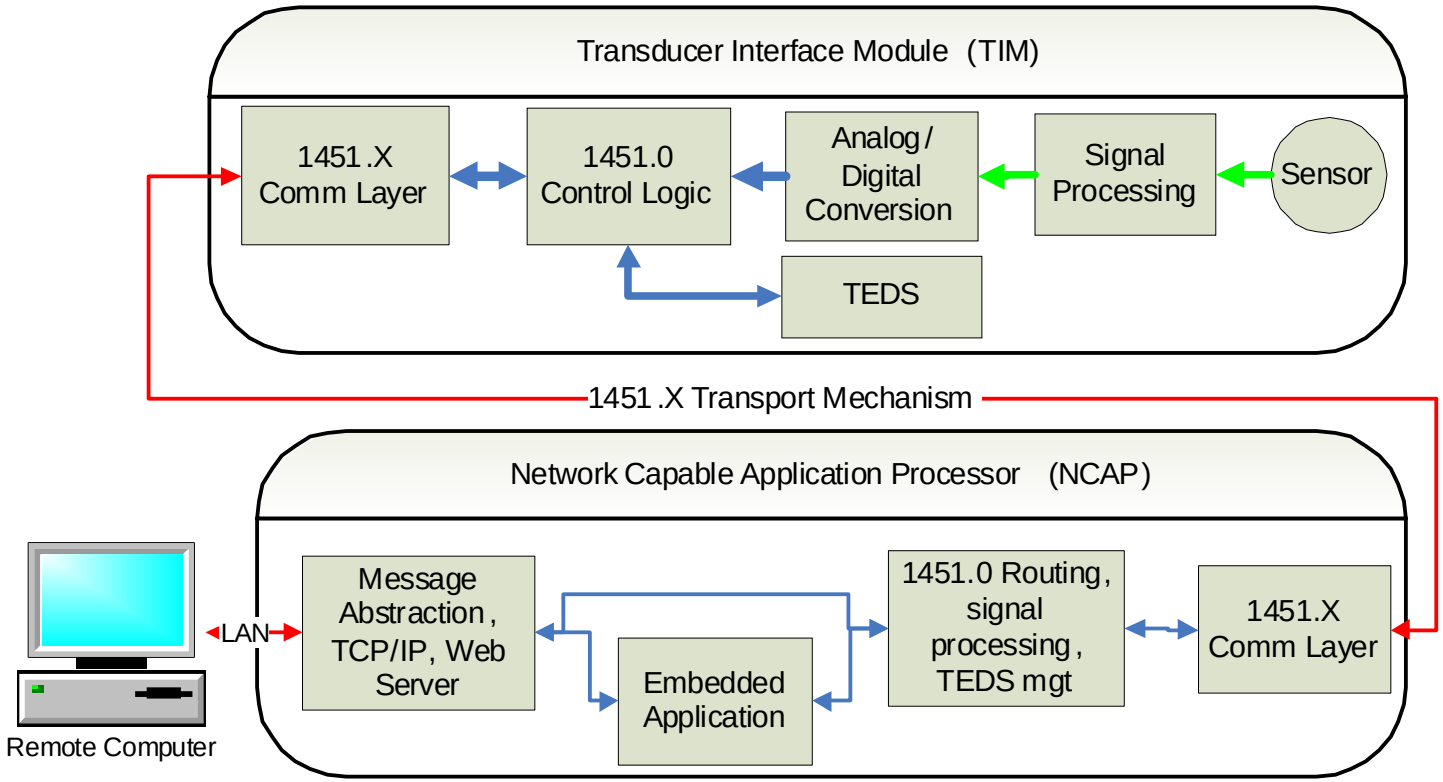
But the Complexity!

- A comprehensive standard is necessarily complex
- There was little adoption of the original IEEE 1451.2 (TII) standard because of its perceived complexity
- Manual preparation of the TEDS is not practical
- A TEDS compiler is needed
- A compliance test procedure is also desirable to prove that the design is correct



Munch –The scream

A review of the
IEEE 1451 Smart Transducer Concept



IEEE 1451.0 (Dot 0) Format

- Required TEDS [Memory block with defined format]
  - MetaTEDS
  - Channel TEDS
  - Calibration TEDS (unless SI units)
  - Xdr-name TEDS
  - Phy TEDS
  - Also optional TEDS

- Data Transmission [specific octet format]
  - TEDS/Status requests
  - Triggering and configuration
  - Sensor read commands and data return
  - Actuator write commands and data sending

TEDS Format

- General format for each TEDS section:

Field	Description	Data Type	Number of Bytes
-------	TEDS Length	UInt32	4 bytes
1 to N	Data Block	Variable	Variable
-------	Checksum	Uint16	2 bytes

- Binary TEDS Tuple format for each data block:

  Type-Length-value (TLV)

  Example: 01 02 A3 04

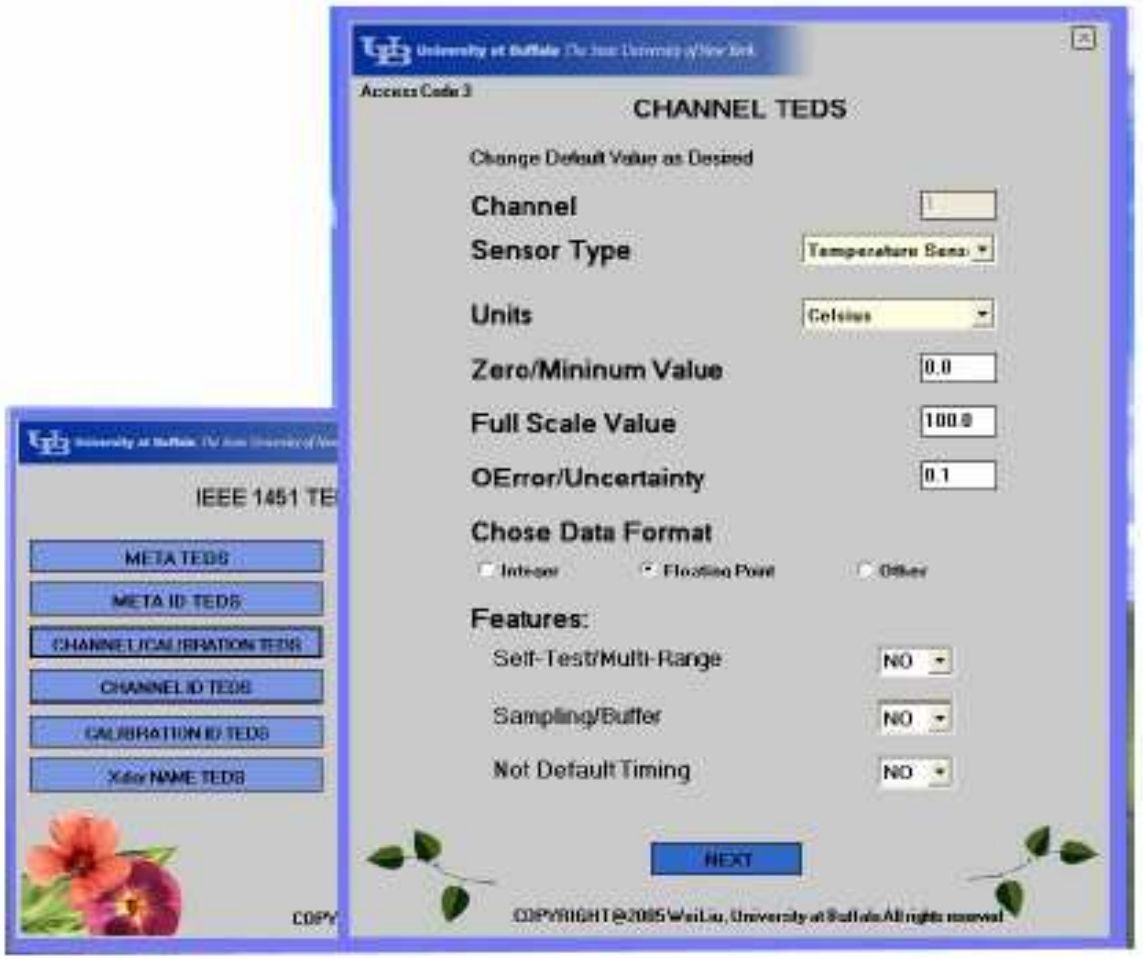
  Field type is 1, Length is 2 bytes, field value is “A304” hex

- Field example: Meta-TEDS (TEDS # 1)

  13: Number of Implemented Transducer Channels (default=1)

TEDS Compiler

- Part of Ph. D. thesis
  Wai Liu
  (Univ. at Buffalo)
- Copy of thesis is available free



TEDS Sections Implemented

- Meta TEDS
- Meta ID TEDS
- Transducer Channel TEDS
- Transducer Channel ID TEDS
- Calibration TEDS
- Calibration ID TEDS
- XdrcName TEDS

Referenced by TEDS section/access code (e.g. #1 for Meta-TEDS)

Standard Transducer Units
(binary format)

SI Based Units

Base Quantity	Name	Unit Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Field	Description	Data Type	Number of octets
1	Physical units interpretation	UInt8	1
2	(2 * <exponent of radians>) + 128	UInt8	1
3	(2 * <exponent of steradians>) + 128	UInt8	1
4	(2 * <exponent of meters>) + 128	UInt8	1
5	(2 * <exponent of kilograms>) + 128	UInt8	1
6	(2 * <exponent of seconds>) + 128	UInt8	1
7	(2 * <exponent of amperes>) + 128	UInt8	1
8	(2 * <exponent of kelvins>) + 128	UInt8	1
9	(2 * <exponent of moles>) + 128	UInt8	1
10	(2 * <exponent of candelas>) + 128	UInt8	1

Dot 0 Command/Response Structure

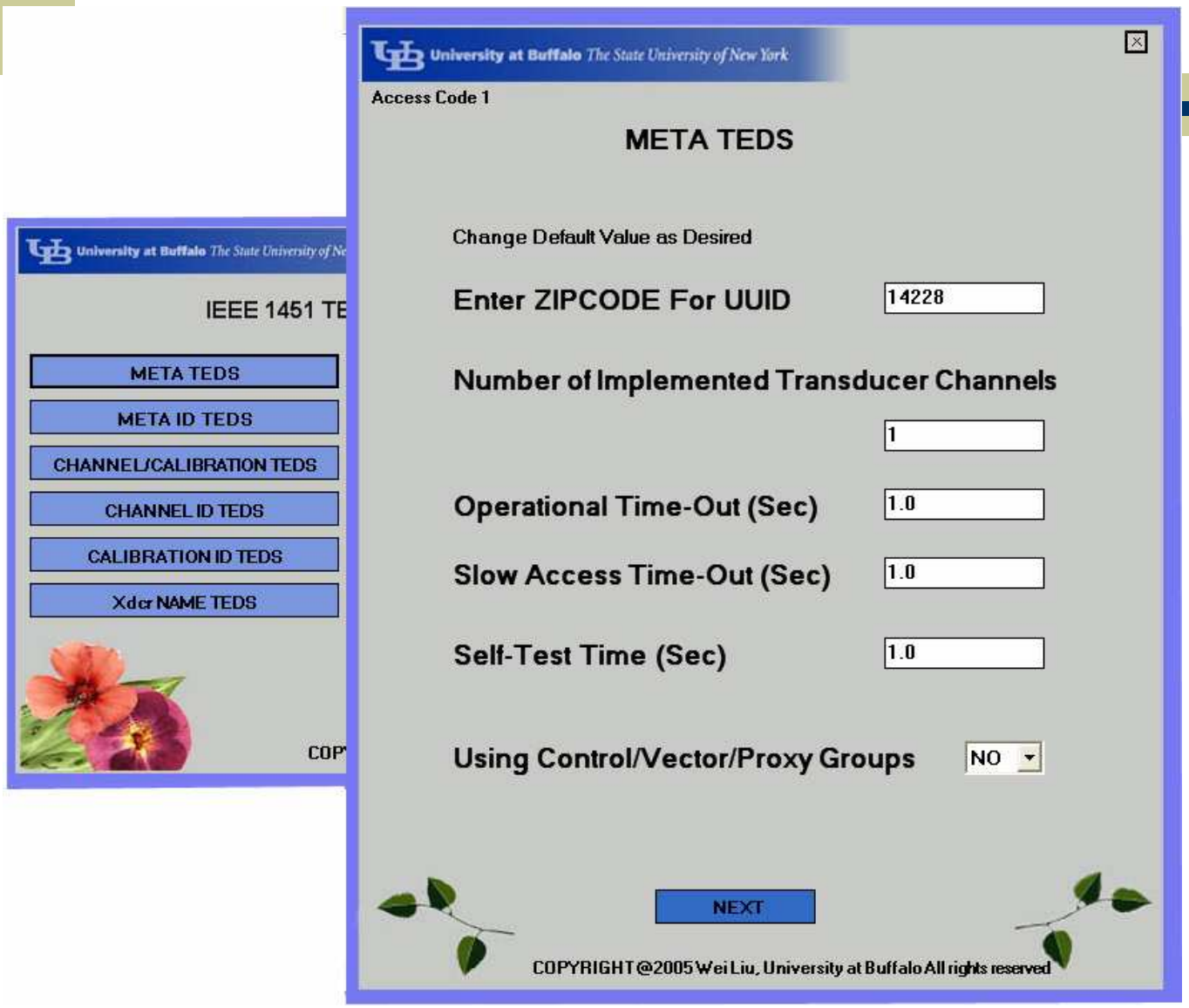
Byte Number	Description
1	Destination Transducer Channel Number (Most significant byte)
2	Destination Transducer Channel Number (Least significant byte)
3	Command Class
4	Command Function
5	Length (Most significant byte)
6	Length (Least significant byte)
7-N	Command dependent bytes

NCAP Command Message Structure

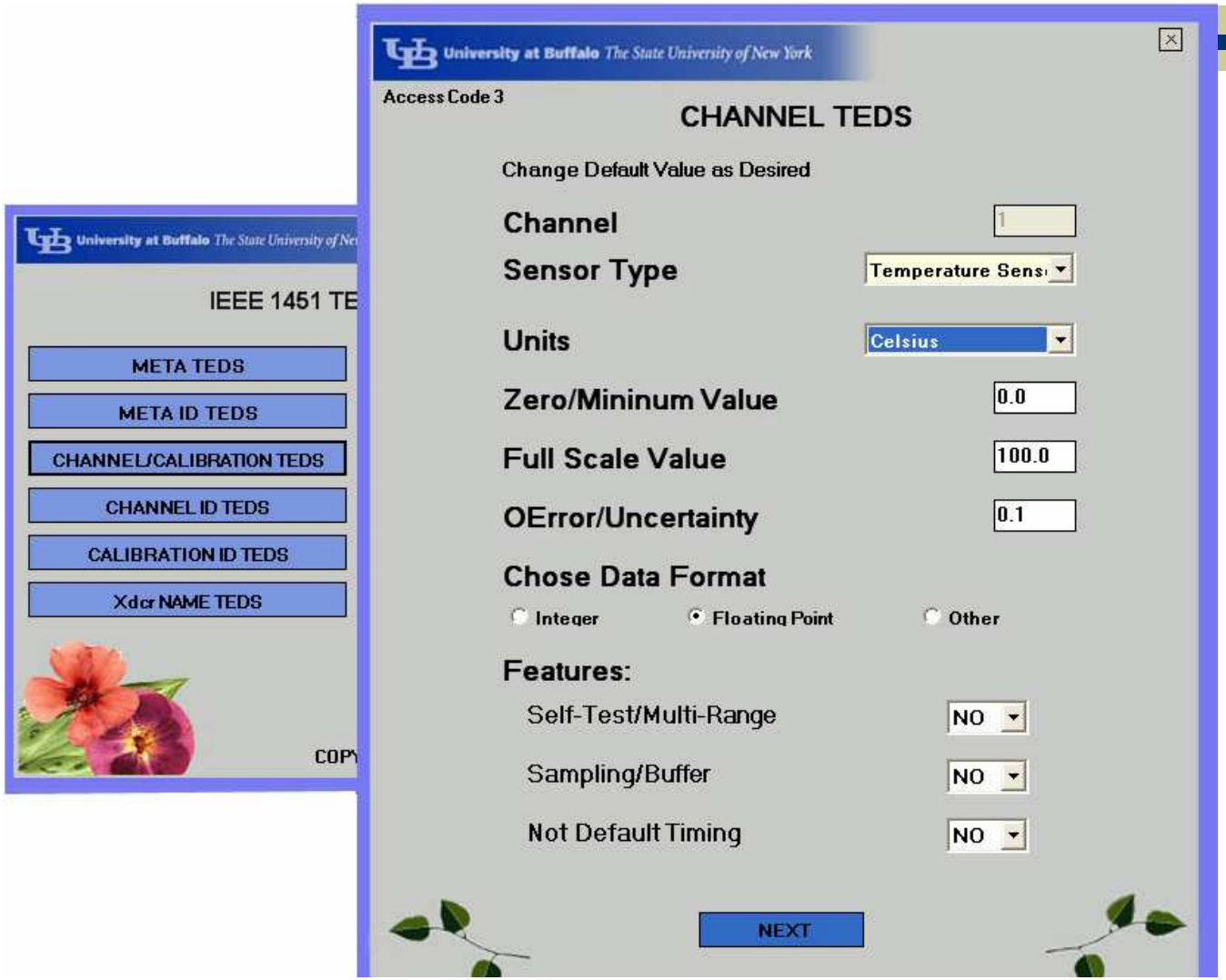
Byte Number	Description
1	Success/Fail Flag
2	Length (Most significant byte)
3	Length (Least significant byte)
4-N	Reply dependent bytes

TIM Reply Message Structure

Meta-TEDS Writer Screen



Channel/Calibration TEDS (for linear sensors)



Text Based TEDS
(human readable)

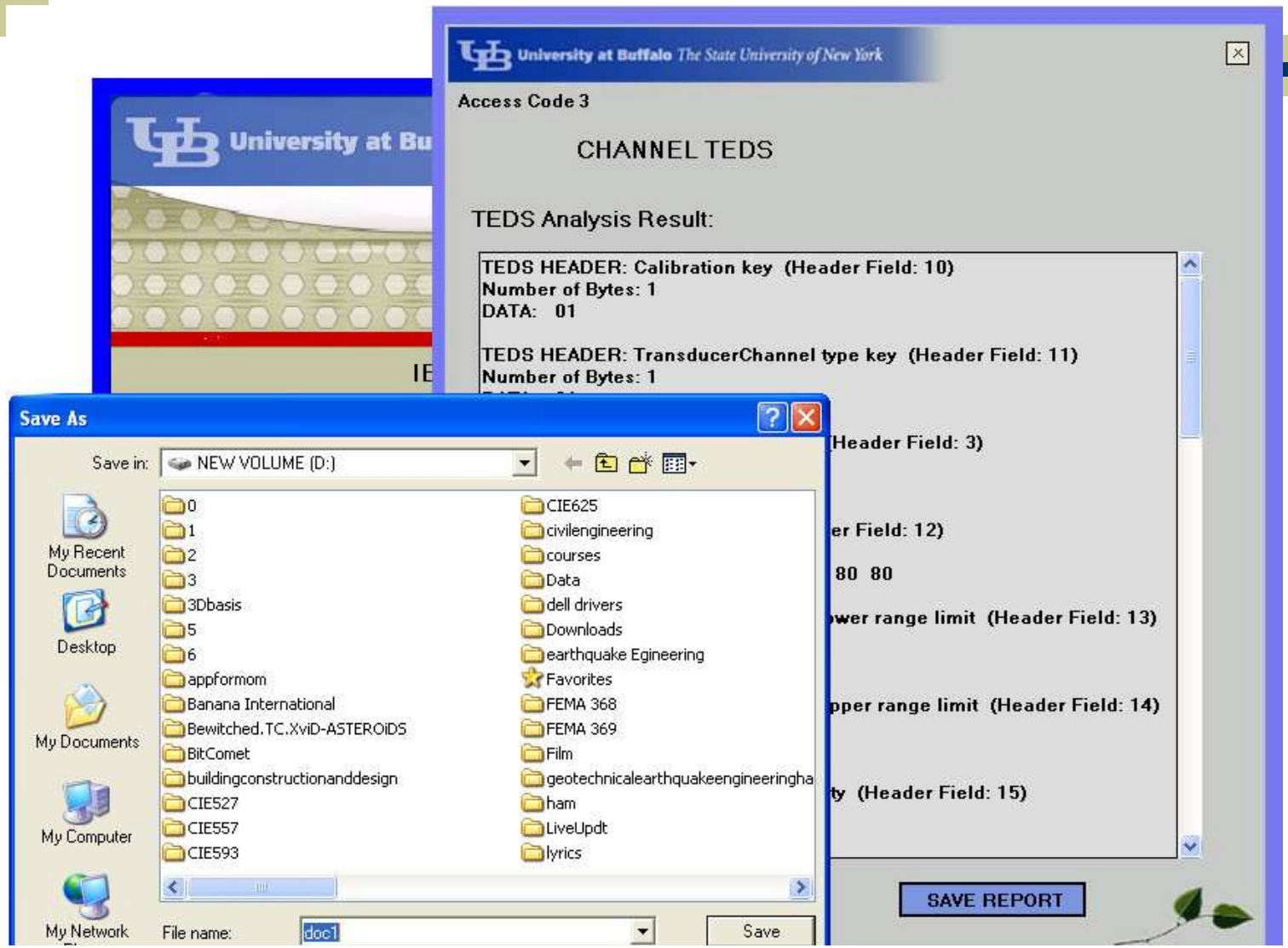
- Meta ID TEDS
- Transducer Channel ID TEDS
- Calibration ID TEDS
- XdcrName TEDS (required)

ASCII or XML – multiple languages available

EN: English

QC: computer language (additional data)

TEDS Reader


University at Buffalo The State University of New York
Access Code 3
CHANNEL TEDS
TEDS Analysis Result:
TEDS HEADER: Calibration key (Header Field: 10)
Number of Bytes: 1
DATA: 01
TEDS HEADER: TransducerChannel type key (Header Field: 11)
Number of Bytes: 1
Header Field: 3)
er Field: 12)
80 80
wer range limit (Header Field: 13)
pper range limit (Header Field: 14)
ty (Header Field: 15)
SAVE REPORT
Save As
Save in: NEW VOLUME (D:)
My Recent Documents
Desktop
My Documents
My Computer
My Network
0
1
2
3
3Dbasis
5
6
appformom
Banana International
Bewitched.TC.XviD-ASTEROiDS
BitComet
buildingconstructionanddesign
CIE527
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IEEE 451 TIM Compliance Tester

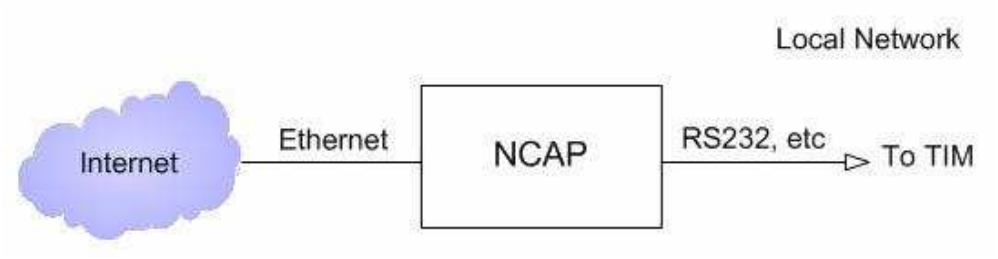
- TIM (Transducer Interface Module) is most complex and done by sensor design engineers
  (TIM tester can be used by the few NCAP designers)
- Tester verifies compliance of a TIM to IEEE 1451.0 (Dot 0) protocol
- Focus is on TEDS checking and data transfer format
- Physical device compliance not checked (part of other standards, e.g. RS485, Bluetooth)
- Tester uses serial bus (RS232)
- Testing may be done by Internet

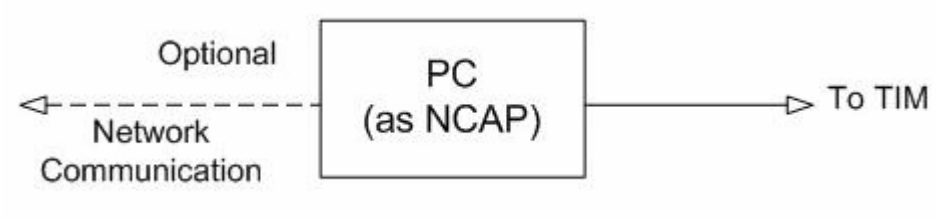
Standard TIM/NCAP Configurations

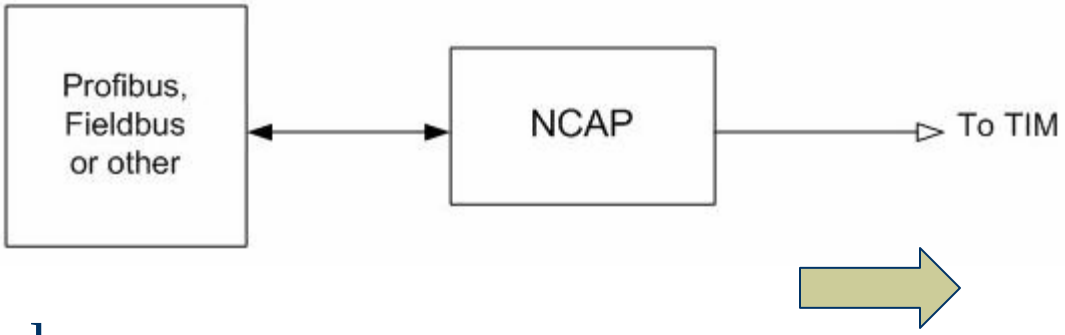
The following 3 slides describe TIM and NCAP configurations for which the TIM tester can be used

Network side (NCAP) options (wired)

- Internet/Ethernet
- PC Readout
- Industrial network



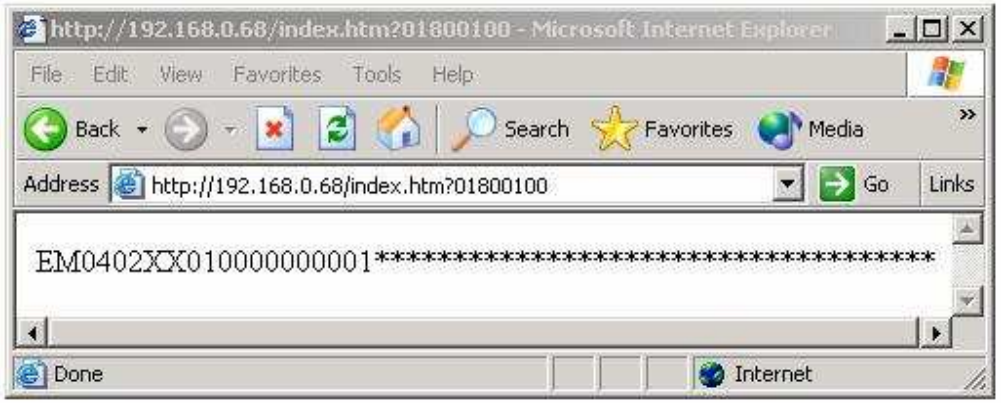




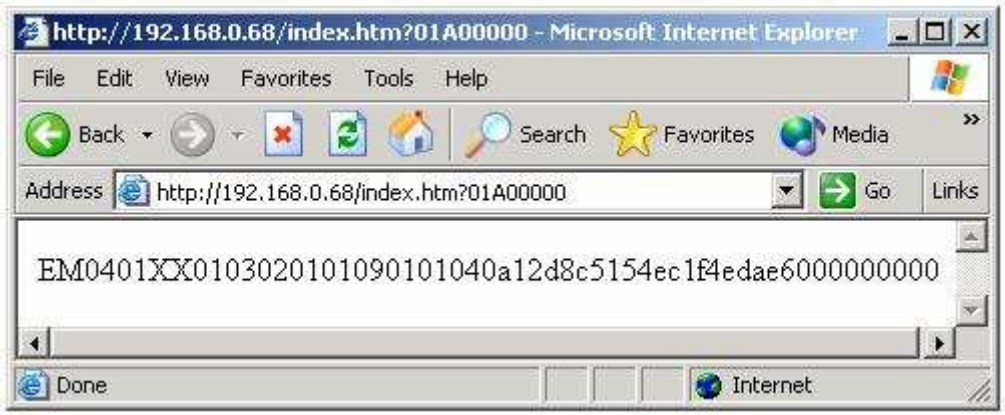
All use Dot 0 protocol

Data Readout Examples
(via Internet)

- Sensor data converted to ASCII for display

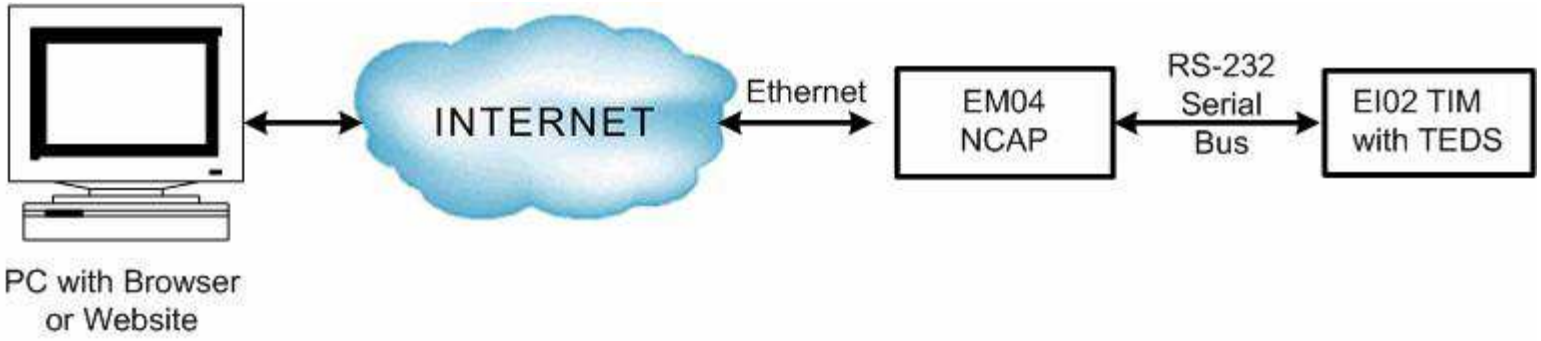


- TEDS data is displayed in hexadecimal form



Prototype TIM and NCAP

- NCAP interfaces to Internet via Ethernet



TEDS Compliance Tester Retrieval Sequence

- Read TIM Version
- Read IEEE p1451.0 Version
- Query Meta ID TEDS
- Query Meta TEDS
- Get Meta TEDS Content
- Query Transducer Channel TEDS
- Get Transducer Channel TEDS Content
- Query Calibration TEDS
- Get Calibration TEDS Content
- Query Transducer Channel ID TEDS
- Query Calibration ID TEDS

TIM Tester (Operating Mode)

Similar test sequence for Idle Mode

TIM Tester – Data retrieval

Serial Bus Format
and Relation to other Networks

- Tester uses RS232 serial bus only but…
- Interfaces to other physical devices (USB, RS485, Bluetooth, Zigbee, ….) available.
- TEDS retrieval is one feature
- Sensor data read (protocol check) for each channel:

  Idle mode – full scale value of sensor reading

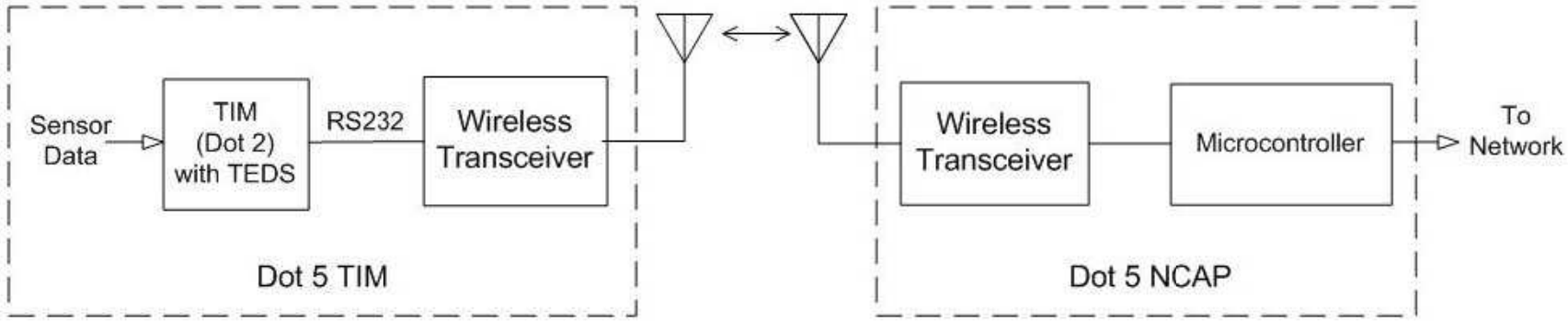
  (Checked against TEDS, error flag is not correct)

  Operating mode – actual sensor reading

  (Must be within sensor range)

Example – Wireless Connection

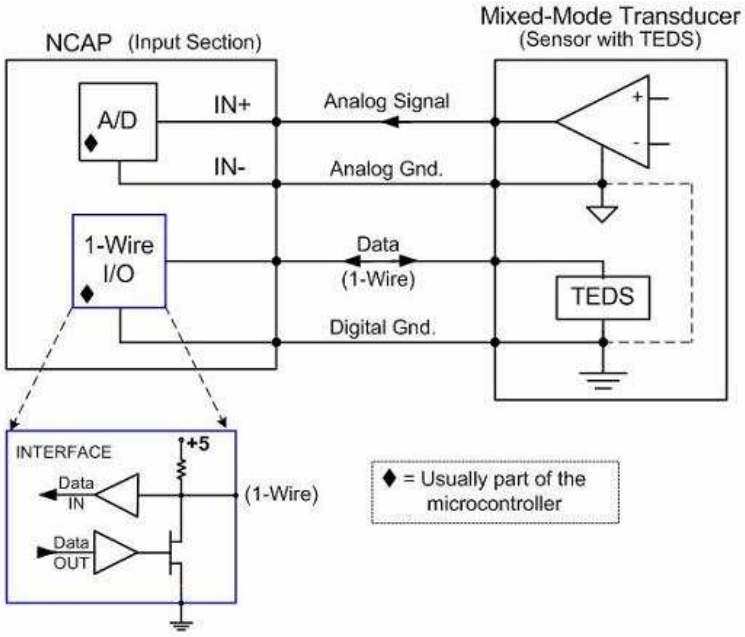
- Wireless modules with RS232 I/O when connected to Dot 2 TIMS are similar to IEEE 1451.5 TIMs (wireless version of IEEE 1451).
- Data format and TEDS are the same (both follow the Dot 0 standard)..

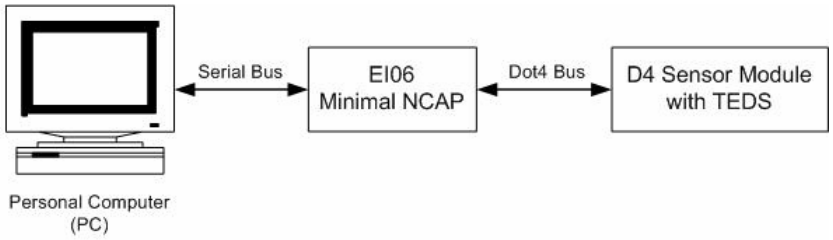


Dot 5 TIM built from a Dot 2 TIM and wireless transceiver

Alternative Tester for Dot 4 TEDS

IEEE 1451.4 (only) does not use the Dot 0 format TEDS. This is a small, TEDS-only version (no digital data format is specified by the standard).





Dot 4

Transducer Electronic Data Sheet (Dot 4 TEDS)

- UUID (Universal **Unique** Identifier)

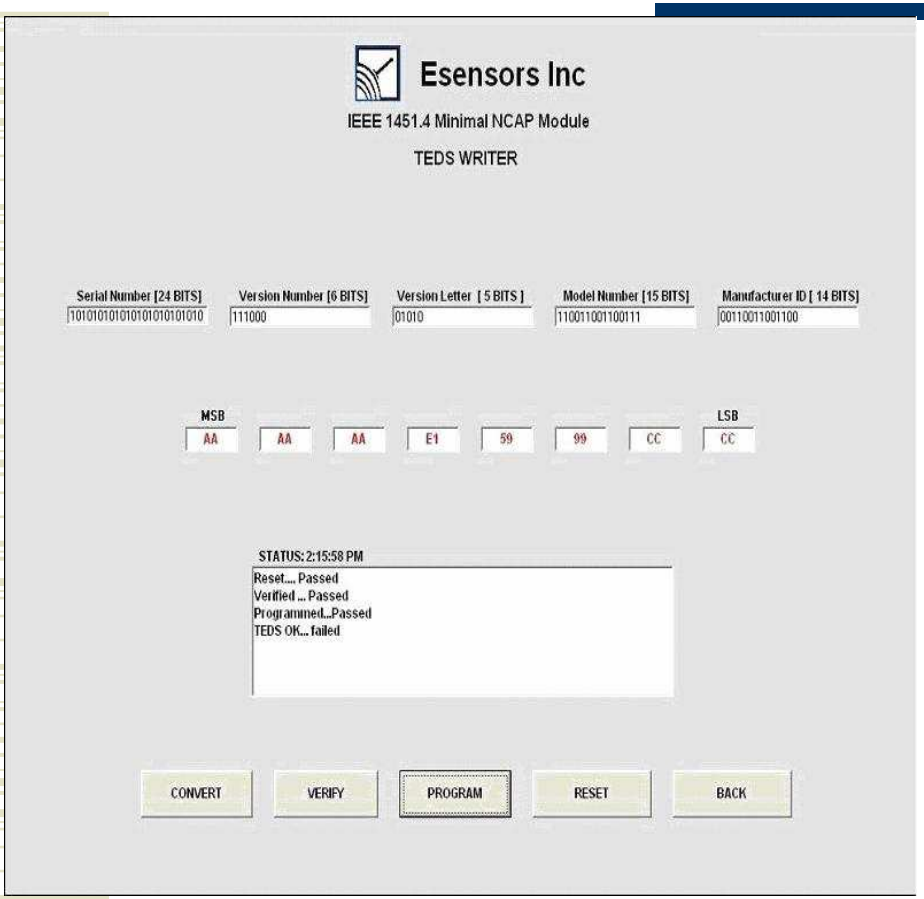
  Supplied by EEPROM (DS2433) manufacturer (6 bytes)
- Basic TEDS (8 bytes)
  - Model Number (15 bits)
  - Version Letter (5 bits, A-Z)
  - Version Number (6 bits)
  - Manufacturer ID (14 bits)
  - Serial Number (6 bits)
- Manufacturer's TEDS

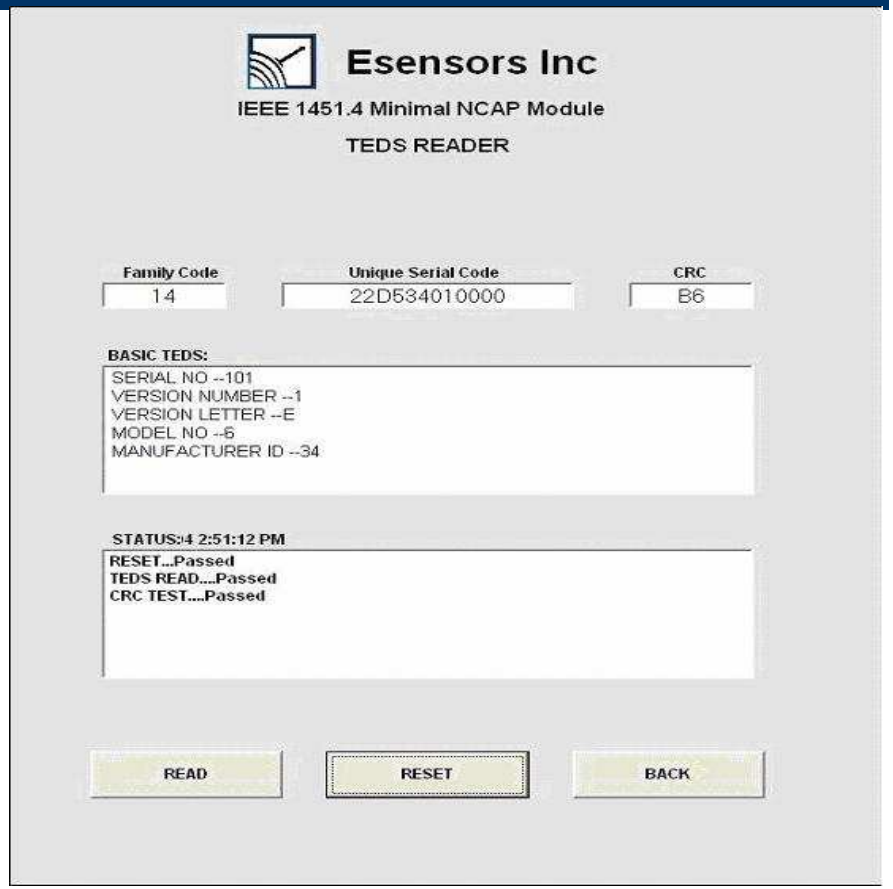
  Sensor type and calibration parameters (16 bytes)

Conversion to Dot 0 TEDS possible (but not unique)

Dot 4

Dot 4 TEDS Writer and Reader
(PC Screens)





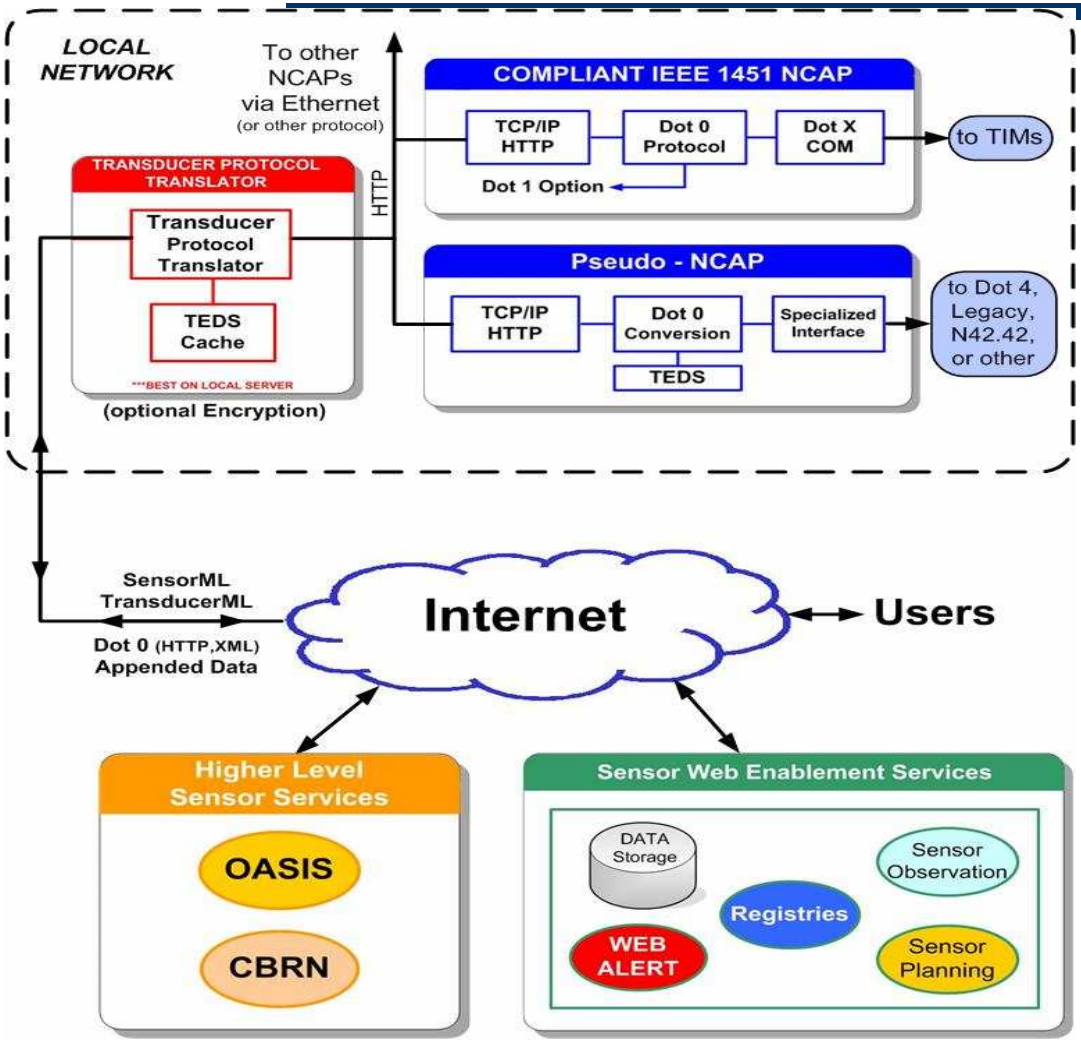
Writer Dot 4 Reader

Naming the IEEE 1451 Standard
-- a suggestion --

TEDS*up*

- **T**ransducer **E**lectronic **D**ata **S**heet **U**niversal **P**rotocol

Harmonization of IEEE 1451 with other sensor standards



Summary

- We have developed an IEEE 1451 TEDS compiler (writer/reader), including a linear calibration procedure
- We have developed and tested an Internet-compatible Dot 0 compliance tester using a serial bus (with extensions to other buses/networks)
- A Dot 4 TEDS Reader/writer was described.
- Harmonization suggestions were given.

Further information: designer@eesensors.com

Backup Slides

An IEEE 1451 TEDS Compiler
and Serial Network Compliance Tester

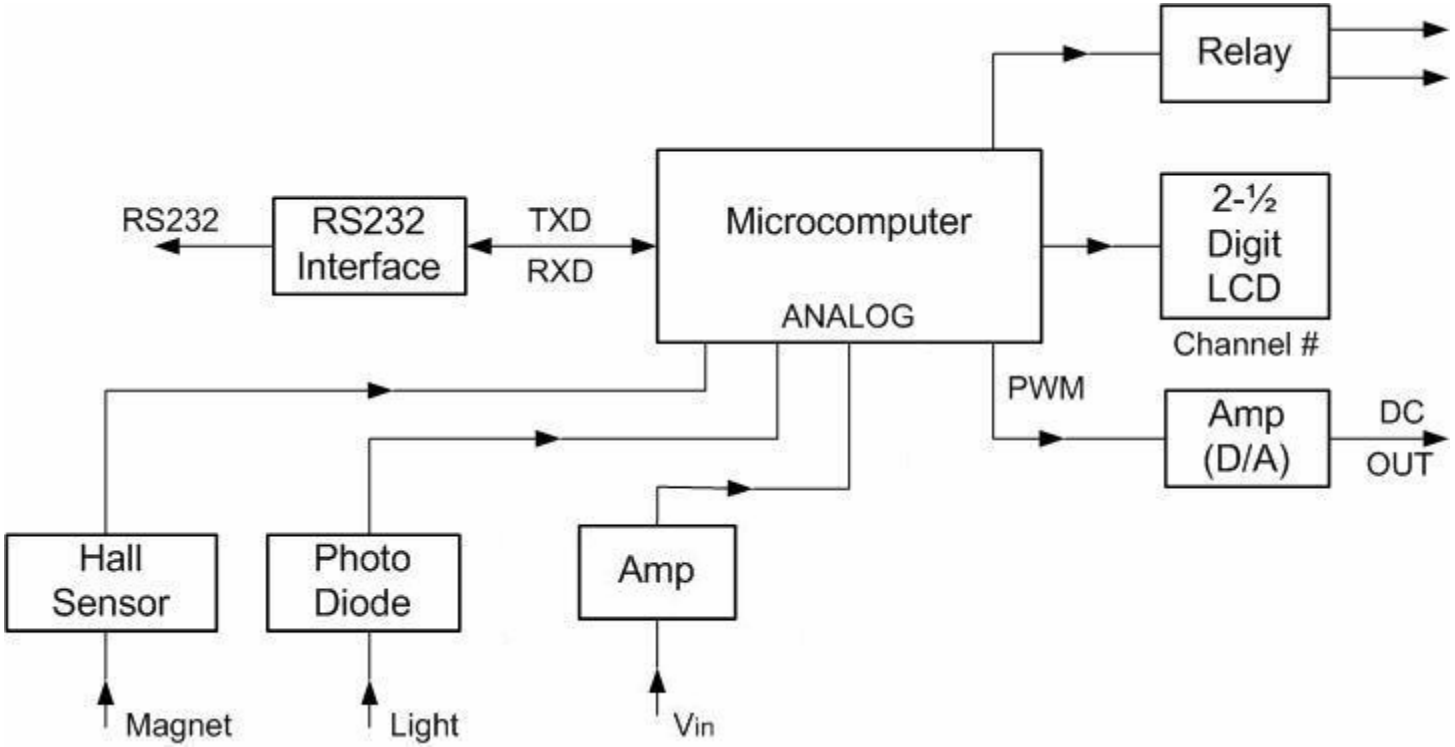
www.eesensors.com

UUID Format

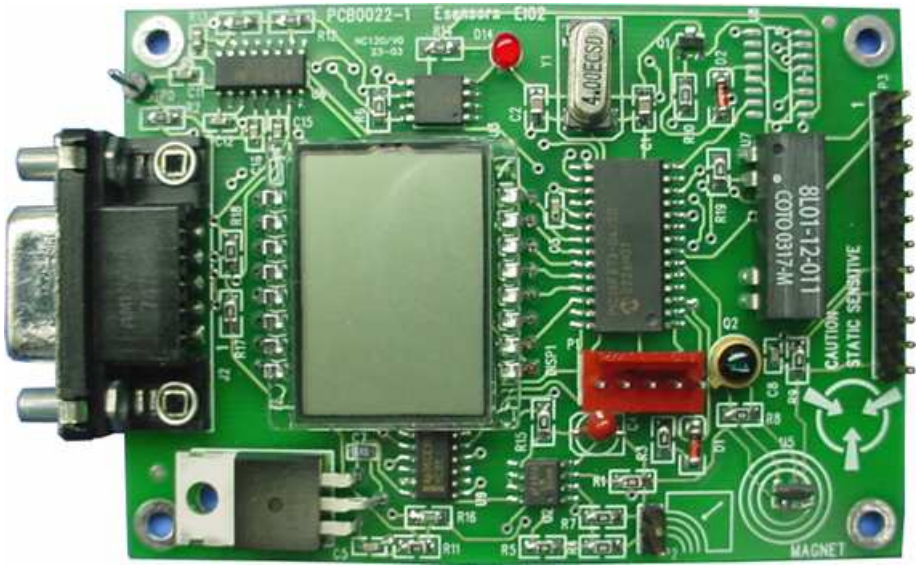
Bit Number	Data Description
Bit 1	Bit 1=0(North) Bit 1=1(South)
Bit 2-Bit 21	Manufacturer Latitude (Binary format)
Bit 22	Bit 22=0(East) Bit 22=1(West)
Bit 23-Bit 42	Manufacturer Longitude (Binary format)
Bit 43-Bit 46	Arbitrary Field=0000 (Binary format)
Bit 47-Bit 58	Year (Binary format)
Bit 59-Bit 80	Time (Binary format)

Meta-TEDS (#1), field 4 (10 bytes)

Block Diagram of a Prototype Dot 2 TIM or Smart Transducer



Prototype Dot 2 (RS232) TIM
(with 2 sensors and 1 actuator)

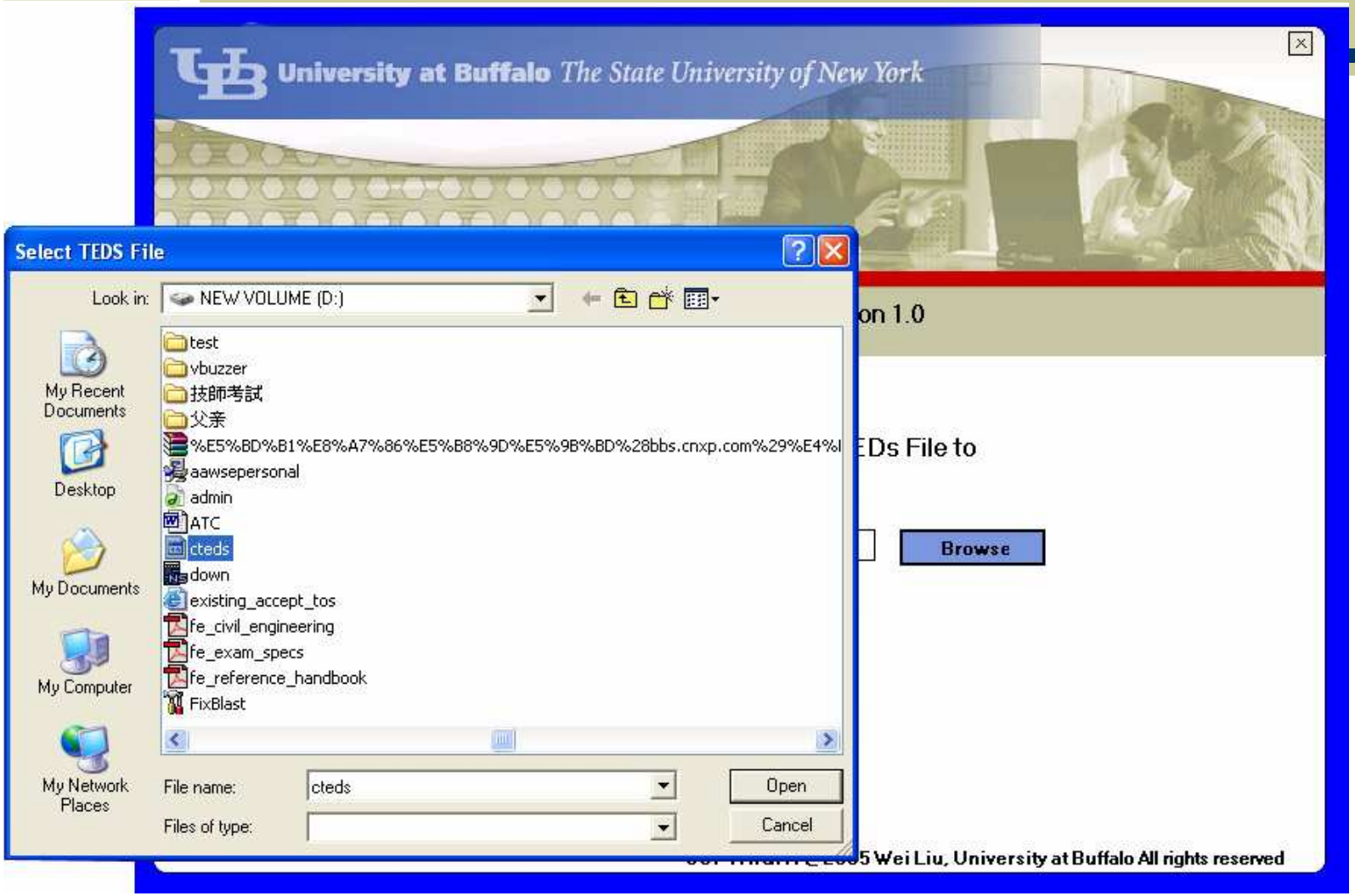


Relay

Photo

Hall effect

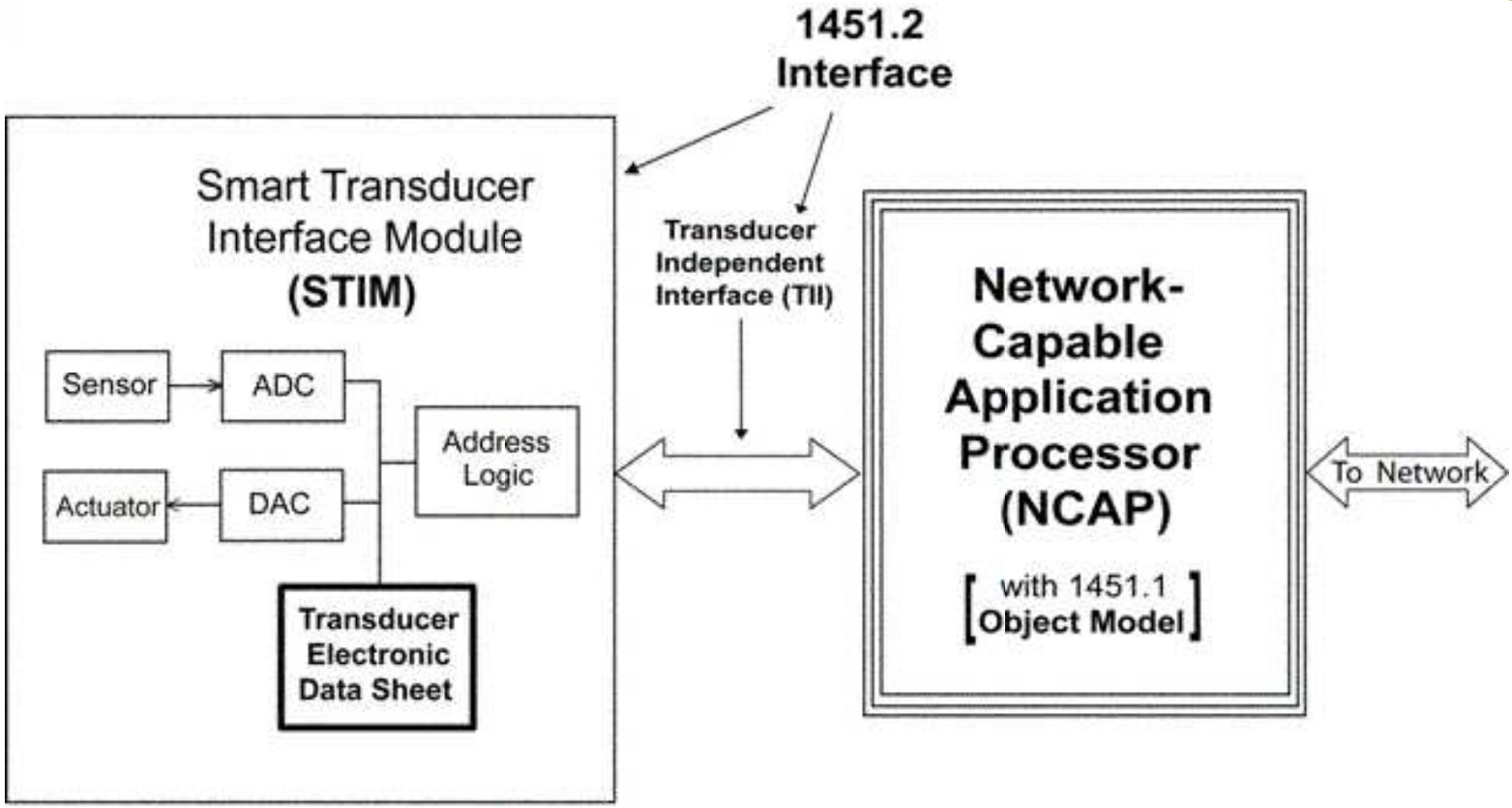
TEDS/Test Data File Save



References

- Wai Liu, “Design of TEDS Writer, Reader and Testing System for Transducer Interface Modules based on the IEEE 1451 Standard“, Ph. D. thesis (SUNY/Buffalo, EE Dept), May 2006.
- R. Johnson, et al “A Standard Smart Transducer Interface” http://ieee1451.nist.gov/Workshop_04Oct01/1451_overview.pdf
- IEEE Std. 1451.2-1907 “IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Format” http://ihome.ust.hk/~yangrd/pdf/ieee14512.pdf
- R. Frank “Understanding Smart Sensors”, 2nd ed, Artech House (2000)
- D. Wobschall, “Websensor Design – Smart sensors with an Internet Address” Proceeding Sensors Expo (Philadelphia, Oct. 2001)
- D. Wobschall, “A Minimal Dot4 NCAP with a Compatible Sensor Bus”, SiCon/05 (Houston).
- www.eesensors.com/IEEE1451

Original IEEE 1451.2 (Dot 2)
With 10-pin Transducer Independent Interface (TII)



Note: New name is TIM (Transducer Interface Module)

IEEE 1451 Parts

- IEEE 1451.0 Protocols & formats (final ballot, 2006)
- IEEE 1451.1 Object model (approved 1999)
- IEEE 1451.2 Serial (approved 1997)*
- IEEE 1451.3 Local network (approved 2003)
- IEEE 1451.4 Analog & TEDS (approved 2004)
- IEEE 1451.5 Wireless (close to final)
- IEEE 1451.6 Open CAN (early approval process)

* Enhancement /revision working group in process

- END